Anatomy of Blood Vessels

• **arteries** carry blood away from heart
• **veins** carry blood back to heart
• **capillaries** connect smallest arteries to veins, exchange material with surrounding tissues
Vessel Wall

- **tunica interna**
  - lines the blood vessel and is exposed to blood
  - **endothelium** – simple squamous epithelium overlying a basement membrane and a layer of loose connective tissue
Vessel Wall

- **tunica media**
  - middle layer
  - consists of *smooth muscle*, collagen, and elastic tissue
  - strengthens vessel and prevents blood pressure from rupturing them
  - changes in diameter of the blood vessel brought about by smooth muscle
Vessel Wall

• tunica externa
  – outermost layer
  – consists of loose connective tissue that often merges with that of neighboring blood vessels, nerves, or other organs
  – anchors the vessel and provides passage for small nerves, lymphatic vessels
Aneurysm

- **aneurysm** - weak point in an artery or the heart wall
  - forms a thin-walled, bulging sac that pulsates with each heartbeat and may rupture at any time
  - **most common sites**: abdominal aorta, renal arteries, and arterial circle at the base of the brain
  - can cause pain by putting pressure on other structures
  - can rupture causing hemorrhage
  - result from congenital weakness of the blood vessels or result of trauma or bacterial infections such as syphilis
    - most common cause is atherosclerosis and hypertension
Capillaries

- **capillaries** - site where nutrients, wastes, and hormones pass between the blood and tissue fluid through the walls of the vessels (exchange vessels)
  - composed of *endothelium and basal lamina*
Three Types of Capillaries

• **continuous capillaries** - occur in most tissues

• **fenestrated capillaries** - kidneys, small intestine

• **sinusoids (discontinuous capillaries)** - liver, bone marrow, spleen
Continuous Capillary

Pericyte
Basal lamina
Intercellular cleft
Pinocytotic vesicle
Endothelial cell
Erythrocyte
Tight junction

Figure 20.5
Fenestrated Capillary

Figure 20.6a

Figure 20.6b

(a) Erythrocyte
(b) Nonfenestrated area

b: Courtesy of S. McNutt
Sinusoid in Liver

Figure 20.7
Capillary Beds

• capillaries organized into networks called **capillary beds**
  – usually supplied by a single **metarteriole**

• **precapillary sphincters** control which beds are well perfused
  – **when sphincters open**
    • capillaries are well perfused with blood and engage in exchanges with the tissue fluid
  – **when sphincters closed**
    • blood bypasses the capillaries
    • flows through thoroughfare channel to venule
when sphincters are open, the capillaries are well perfused. 

three-fourths of the capillaries of the body are shut down.
when the sphincters are closed, little to no blood flow occurs (skeletal muscles at rest)
Veins (Capacitance Vessels)

- greater capacity for blood containment than arteries
- thinner walls, flaccid, less muscular and elastic tissue
- collapse when empty, expand easily
- have steady blood flow
- merge to form larger veins
- subjected to relatively low blood pressure
  - remains 10 mm Hg with little fluctuation
Blood Flow Pathway

• venous sinuses
  – veins with especially thin walls, large lumens, and no smooth muscle
  – Example: coronary sinus of the heart
  – not capable of vasomotion
Varicose Veins

- Blood pools in the lower legs in people who stand for long periods stretching the veins
  - Cusps of the valves pull apart in enlarged superficial veins further weakening vessels
  - Blood backflows and further distends the vessels, their walls grow weak and develop into varicose veins

- Hereditary weakness, obesity, and pregnancy also promote problems

- Hemorrhoids are varicose veins of the anal canal
Circulatory Routes

• simplest and most common route
  – heart → arteries → arterioles → capillaries → venules → veins
  – passes through only one network of capillaries from the time it leaves the heart until the time it returns

• portal system
  – blood flows through two consecutive capillary networks before returning to heart
    • between hypothalamus and anterior pituitary
    • in kidneys
    • between intestines to liver
(a) Simplest pathway
   (1 capillary bed)

(b) Portal system
    (2 capillary beds)

(c) Arteriovenous anastomosis
    (shunt)

(d) Venous anastomoses
(e) Arterial anastomoses
Anastomoses

- **anastomosis** – the point where two blood vessels merge
- **arteriovenous anastomosis** (shunt)
  - artery flows directly into vein bypassing capillaries
  - not common, damage, surgery, congenital defect
- **venous anastomosis**
  - most common
  - one vein empties directly into another
  - reason vein blockage less serious than an arterial blockage
- **arterial anastomosis**
  - two arteries merge
  - provides **collateral (alternative) routes** of blood supply to a tissue
  - coronary circulation and around joints
Blood Pressure

- blood pressure (bp) – the force that blood exerts against a vessel wall
- measured at **brachial artery** of arm using **sphygmanometer**
- two pressures are recorded:
  - **systolic pressure**: peak arterial BP taken during ventricular contraction (ventricular systole)
  - **diastolic pressure**: minimum arterial BP taken during ventricular relaxation (diastole) between heart beats
- normal value, young adult: **120/75 mm Hg**
Abnormalities of Blood Pressure

• **hypertension** – high blood pressure
  – chronic is resting BP > 140/90
  – consequences
    • can weaken small arteries and cause aneurysms

• **hypotension** – chronic low resting BP
  – caused by blood loss, dehydration, anemia
Blood Pressure

• one of the body’s chief mechanisms in preventing excessive blood pressure is the ability of the arteries to **stretch and recoil** during the cardiac cycle

• importance of arterial elasticity
  – expansion and recoil maintains steady flow of blood throughout cardiac cycle, smoothes out pressure fluctuations and decreases stress on small arteries

• BP rises with age
  – arteries less distensible and absorb less systolic force

• BP determined by **cardiac output, blood volume** and **peripheral resistance**
The graph illustrates the change in systemic blood pressure (in mm Hg) as blood travels from the aorta to the venae cavae. Systolic pressure is indicated by the red line, showing a decrease as the distance from the left ventricle increases. Diastolic pressure, indicated by the green line, also decreases over the same distance. The chart indicates that blood pressure drops significantly as it moves through the small arteries, arterioles, capillaries, and veins, and continues to decline as it enters the large veins and venae cavae.
Control by Arterioles

• arterioles are most significant point of control over peripheral resistance and flow
  – on proximal side of capillary beds and best positioned to regulate flow into the capillaries
  – outnumber any other type of artery, providing the most numerous control points
  – more muscular in proportion to their diameter
    • highly capable of vasomotion

• arterioles produce half of the total peripheral resistance
Regulation of BP and Flow

• **vasomotion** is a quick and powerful way of altering blood pressure and flow

• three ways of controlling vasomotion:
  – local control
  – neural control
  – hormonal control
Local Control of BP and Flow

• **autoregulation** – the ability of tissues to regulate their own blood supply

• **vasoactive chemicals** - substances secreted by platelets, endothelial cells, and perivascular tissue stimulate vasomotion

• **angiogenesis** - growth of new blood vessels
  - occurs in regrowth of uterine lining, around coronary artery obstructions, in exercised muscle, and malignant tumors
  - controlled by growth factors
Neural Control of Blood Vessels

- vessels under remote control by the central and autonomic nervous systems

- **vasomotor center** of medulla oblongata exerts sympathetic control over blood vessels throughout the body
  - stimulates most vessels to constrict, but dilates vessels in skeletal and cardiac muscle to meet demands of exercise
    - precapillary sphincters respond only to local and hormonal control due to lack of innervation
  - vasomotor center is the integrating center for three autonomic reflexes
    - Baroreflexes – carotid sinuses
    - Chemoreflexes – aortic and catotid bodies
    - medullary ischemic reflex – medulla oblongata
Negative Feedback Control of BP

Figure 20.13
Two Purposes of Vasomotion

• general method of raising or lowering BP throughout the whole body
  – increasing BP requires medullary vasomotor center or widespread circulation of a hormone

• method of rerouting blood from one region to another for perfusion of individual organs
  – either centrally or locally controlled
    • during exercise, sympathetic system reduces blood flow to kidneys and digestive tract and increases blood flow to skeletal muscles
    • metabolite accumulation in a tissue affects local circulation without affecting circulation elsewhere in the body
Routing of Blood Flow

• localized vasoconstriction
  – if a specific artery constricts, the pressure downstream drops, pressure upstream rises
  – enables routing blood to different organs as needed

• examples
  – vigorous exercise dilates arteries in lungs, heart and muscles
    • vasoconstriction occurs in kidneys and digestive tract
  – dozing in armchair after big meal
    • vasoconstriction in lower limbs raises BP above the limbs redirecting blood to intestinal arteries
Blood Flow in Response to Needs

Arterioles shift blood flow with changing priorities.

Figure 20.14

Arterioles shift blood flow with changing priorities.
Capillary Exchange

• **capillary exchange** – two way movement of fluid across capillary walls
  - water, oxygen, glucose, amino acids, lipids, minerals, antibodies, hormones, wastes, carbon dioxide, ammonia

• chemicals pass through the capillary wall by **three routes**
  - through endothelial cell cytoplasm
  - intercellular clefts between endothelial cells
  - filtration pores (fenestrations) of the fenestrated capillaries

• mechanisms involved
  - diffusion, transcytosis, filtration, and reabsorption
Filtration and Reabsorption

• fluid filters out of the arterial end of the capillary and osmotically reenters at the venous end
  – delivers materials to the cell and removes metabolic wastes

• opposing forces
  – blood hydrostatic pressure drives fluid out of capillary
    • high on arterial end of capillary, low on venous end
  – colloid osmotic pressure (COP) draws fluid into capillary
    • results from plasma proteins (albumin)- more in blood

• hydrostatic pressure
  – physical force exerted against a surface by a liquid
    • blood pressure is an example

• capillaries reabsorb about 85% of the fluid they filter
• other 15% is absorbed by the lymphatic system and returned to the blood
### Table: Net Filtration and Reabsorption Forces

<table>
<thead>
<tr>
<th>Arterial end</th>
<th>Forces (mm Hg)</th>
<th>Venous end</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 out</td>
<td>Blood hydrostatic pressure</td>
<td>10 out</td>
</tr>
<tr>
<td>+3 out</td>
<td>Interstitial hydrostatic pressure</td>
<td>+3 out</td>
</tr>
<tr>
<td>33 out</td>
<td>Net hydrostatic pressure</td>
<td>13 out</td>
</tr>
<tr>
<td></td>
<td><strong>Hydrostatic pressures</strong></td>
<td></td>
</tr>
<tr>
<td>28 in</td>
<td>Blood</td>
<td>28 in</td>
</tr>
<tr>
<td>−8 out</td>
<td>Tissue fluid</td>
<td>−8 out</td>
</tr>
<tr>
<td>20 in</td>
<td>Oncotic pressure (net COP)</td>
<td>20 in</td>
</tr>
<tr>
<td>13 out</td>
<td>Net filtration or reabsorption pressure</td>
<td>7 in</td>
</tr>
</tbody>
</table>

**Net filtration pressure:** 13 out

**Net reabsorption pressure:** 7 in
Edema

• **edema** – the accumulation of excess fluid in a tissue
  – occurs when fluid filters into a tissue faster than it is absorbed

• three primary causes
  – **increased capillary filtration**
    • kidney failure, histamine release, old age, poor venous return
  – **reduced capillary absorption**
    • hypoproteinemia, liver disease, dietary protein deficiency
  – **obstructed lymphatic drainage**
    • surgical removal of lymph nodes
Consequences of Edema

• tissue necrosis
  – oxygen delivery and waste removal impaired

• pulmonary edema
  – suffocation threat

• cerebral edema
  – headaches, nausea, seizures, and coma

• severe edema or circulatory shock
  – excess fluid in tissue spaces causes low blood volume and low blood pressure
Mechanisms of Venous Return

- **venous return** – the flow of blood back to the heart
  - **pressure gradient**
    - blood pressure is the most important force in venous return
    - 7-13 mm Hg venous pressure towards heart
    - venules (12-18 mm Hg) to **central venous pressure** – point where the venae cavae enter the heart (~5 mm Hg)
  - **gravity** drains blood from head and neck
  - **skeletal muscle pump** in the limbs
    - contracting muscle squeezed out of the compressed part of the vein
  - **thoracic (respiratory) pump**
    - inhalation - thoracic cavity expands and thoracic pressure decreases, abdominal pressure increases forcing blood upward
      - central venous pressure fluctuates
    - 2mm Hg- inhalation, 6mm Hg-exhalation
    - blood flows faster with inhalation
  - **cardiac suction** of expanding atrial space
Skeletal Muscle Pump

(a) Contracted skeletal muscles

(b) Relaxed skeletal muscles

Figure 20.19 a-b
TIAs and CVAs

- **transient ischemic attacks (TIAs)** – brief episodes of cerebral ischemia
  - caused by spasms of diseased cerebral arteries
  - dizziness, loss of vision, weakness, paralysis, headache or aphasia
  - lasts from a moment to a few hours
  - often early warning of impending stroke

- **stroke**
  - sudden death of brain tissue caused by ischemia
    - atherosclerosis, thrombosis, ruptured aneurysm
  - effects range from unnoticeable to fatal
    - blindness, paralysis, loss of sensation, loss of speech common
  - recovery depends on surrounding neurons, collateral circulation
Major Systemic Arteries

• supplies oxygen and nutrients to all organs
Major Systemic Veins

- deep veins run parallel to arteries while superficial veins have many anastomoses
Hypertension

- **hypertension** – most common cardiovascular disease affecting about 30% of Americans over 50

- “the silent killer”
  - major cause of heart failure, stroke, and kidney failure
    - damages heart by increasing afterload
      - myocardium enlarges until overstretched and inefficient
    - renal arterioles thicken in response to stress
      - drop in renal BP leads to salt retention (aldosterone) and worsens the overall hypertension

- **primary hypertension**
  - obesity, sedentary behavior, diet, nicotine

- **secondary hypertension** – secondary to other disease
  - kidney disease, hyperthyroidism
Blood Pressure Drugs

• Beta blocker
  – Inhibit beta adrenergic receptors
    • Block effects of epinephrine
    • Resting – heart reduces output lowering blood pressure

• Calcium channel blocker
  – Reduce intracellular calcium in heart muscle and smooth muscle in blood vessels
    • Reduced cardiac output and dilation of blood vessels